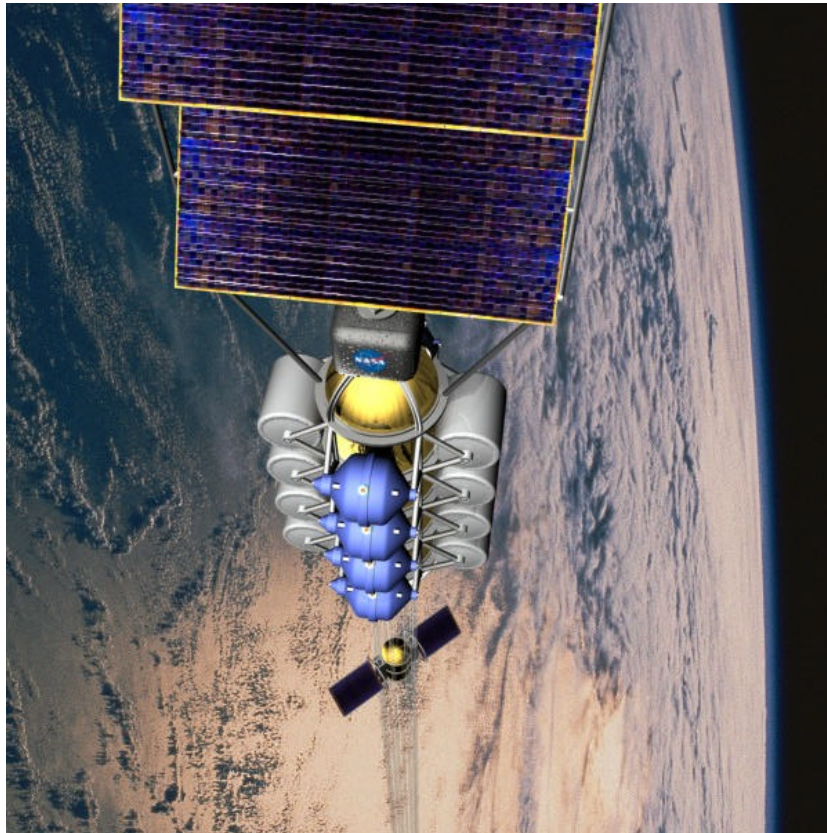




# MXER Tether Boost Stations for IISTP



## Assessment Results

- Operational Orbit: 400 x 13,000 km
- Tether Length: 140 km
- IMLEO: tether station mass + spent upper stage mass
- All masses in metric tonnes

## Transportation Approach

- Momentum-exchange/electrodynamic reboost (MXER) tether facility in Earth orbit boosts spacecraft to high-energy, pre-escape trajectories
- High-thrust propulsion (chemical or NTR) conducts  $\Delta V$  at perigee to target hyperbolic C3.
- Low-thrust propulsion (SEP, NEP, sails) uses lunar swingby to achieve low-C3 heliocentric orbit.
- MXER tether facility supports commercial GEO missions as well as interplanetary spacecraft.

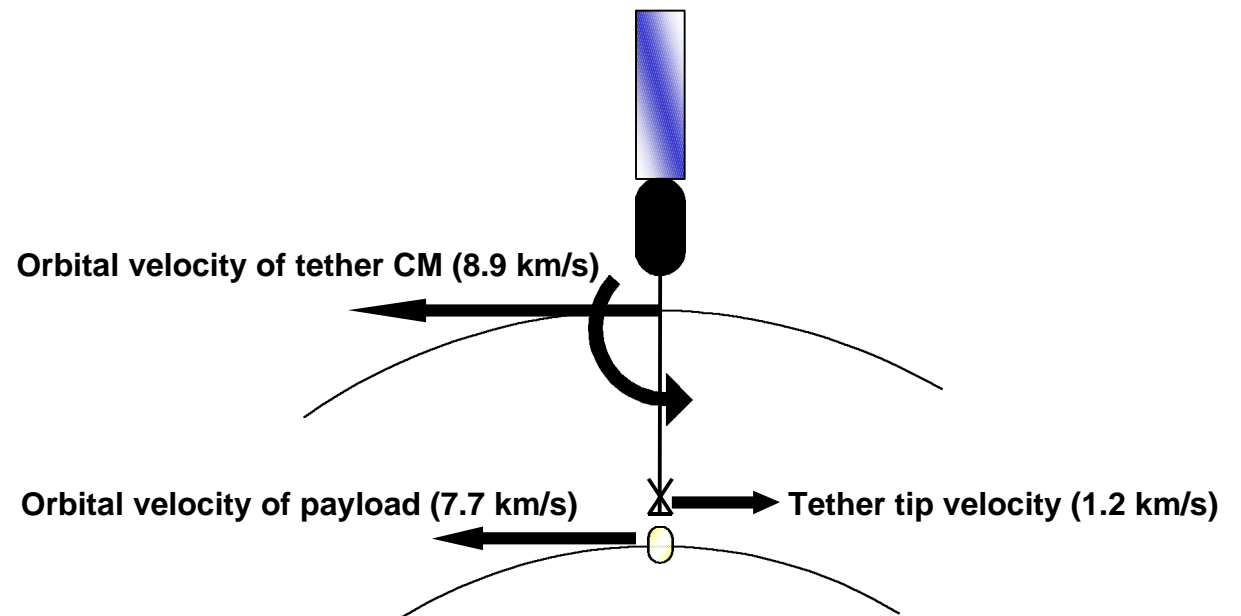
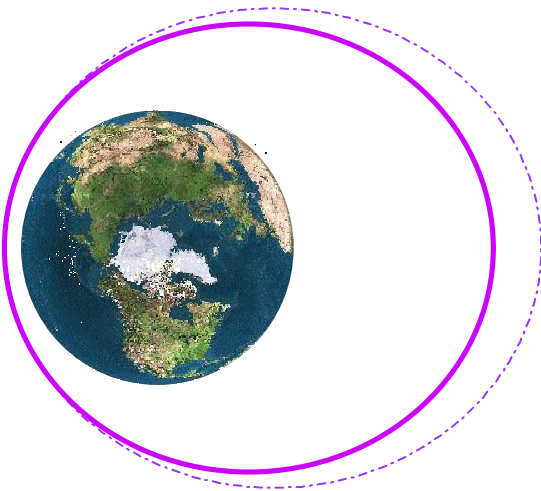
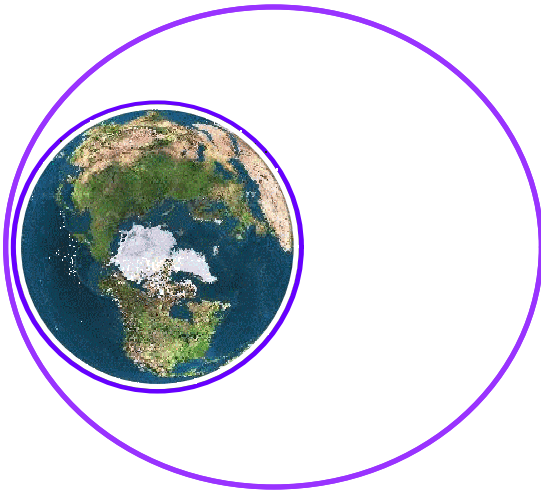
## Issues

- The MXER tether system must be developed and in place (no capability of this type currently exist)
- Development/demonstration of key MXER tether technology and systems is required
- Tether boost timing adds an additional factor to consider in designing and optimizing robust interplanetary trajectories
- Tether facility operations
- Large mass associated with tether (8-10x payload mass)
- Equatorial launch requirement

IMLEO	TLI	48-hr	GTO	LV Requirement
1.8 + 0.3	0.1	0.13	0.2	1 Athena II
12.4 + 2.1	1.0	1.3	2.0	1 Delta IV M+(5,2)
62.7 + 10.5	5.0	6.6	10.0	3 Delta IV H
120.0 + 21.0	10.0	13.2	20.0	6 Delta IV H

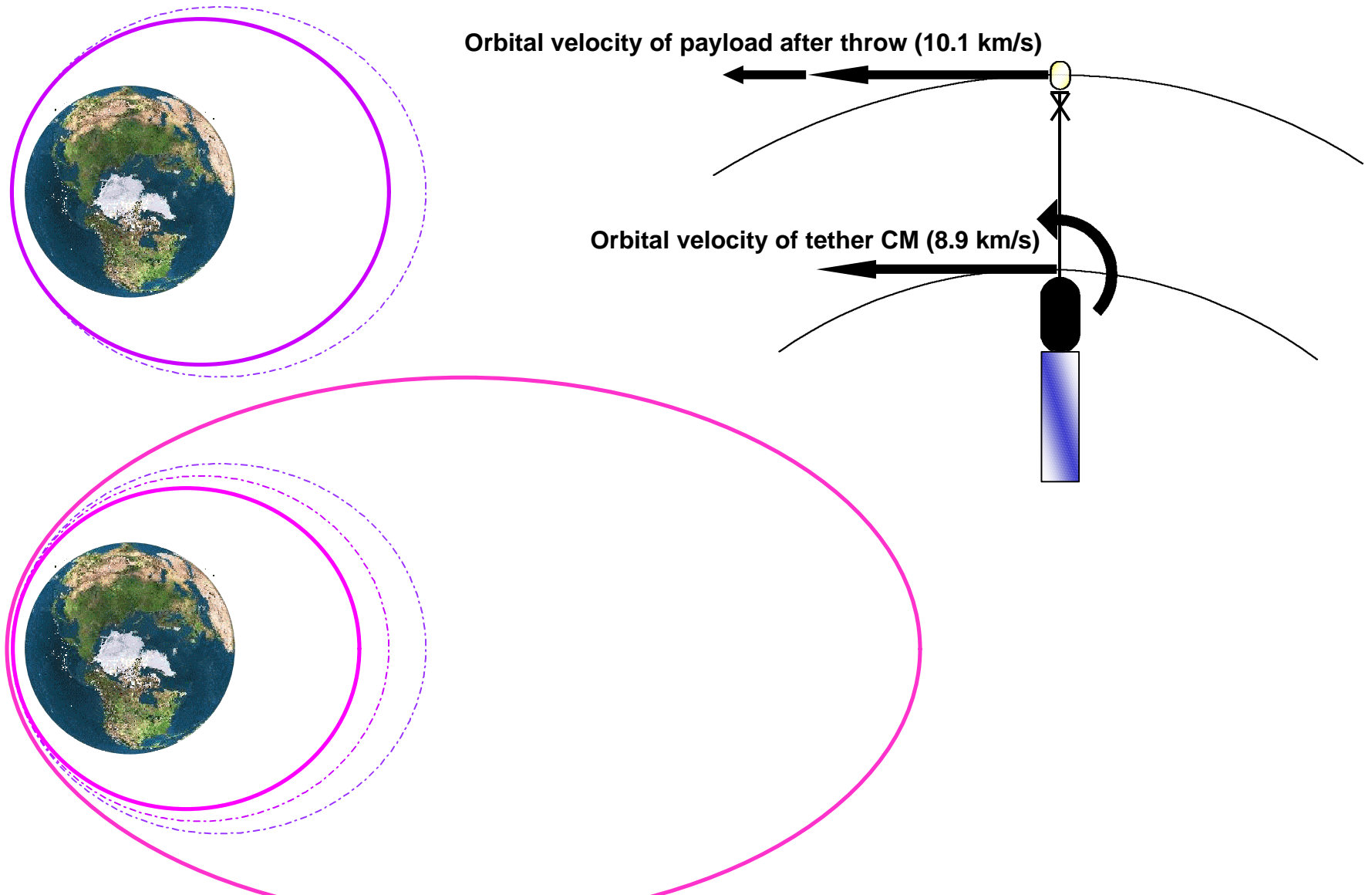


# Fundamentals of Tether Momentum Exchange



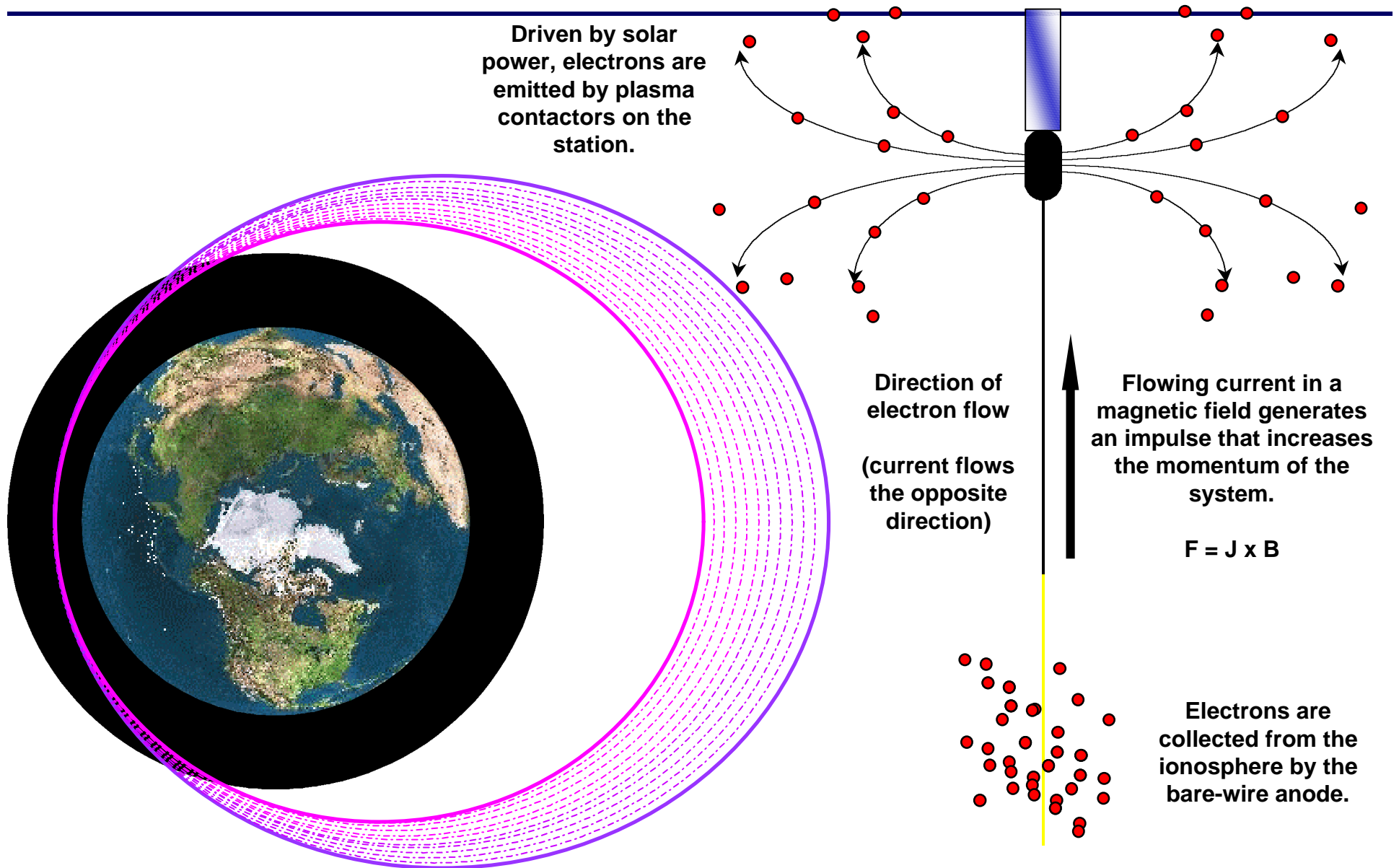


# Fundamentals of Tether Momentum Exchange





# Electrodynamic Reboost of MXER Tether Facility

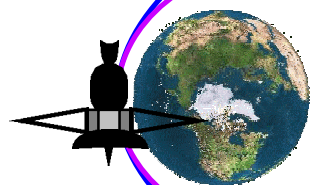




# Hyperbolic Injection for High Thrust Propulsion

Geosynchronous orbit

High-energy payload orbit



Spacecraft executes an injection  $\Delta V$  at perigee to target correct departure  $C3$ .

$$\Delta V = \sqrt{(C3 + 2\mu/r) - \mu(2/r - 1/a)}$$



Spacecraft executes a plane change  $\Delta V$  at apogee to target departure declination.

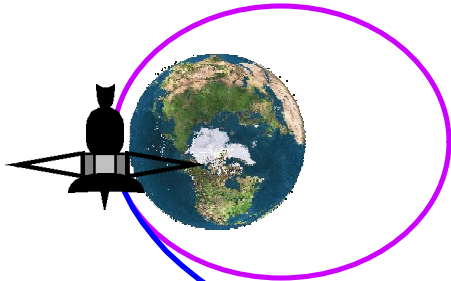
Plane change  $\Delta V$  is proportional to velocity; hence, a plane change at apogee requires much less  $\Delta V$  than a maneuver at perigee.

$$\Delta V = 2 V \sin(\Delta i / 2)$$



## Hyperbolic Injection for Low Thrust Propulsion

**MXER Tether Station injects spacecraft into trans-lunar injection (TLI) trajectory**

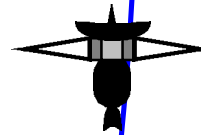


**Spacecraft conducts a prograde lunar flyby.**

**Lunar gravity assist injects payload into low-C3 heliocentric orbit.**



**High-energy elliptical orbit**





# Europa Capture using Electrodynamic Tethers

(all to scale except Europa)

